

Chapter 3. Soils, Hydrology, and Water Quality

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This section briefly describes the soil properties, hydrologic characteristics, and existing water quality conditions of California watersheds in each of the nine RWQCB regions. Appendix D provides a more comprehensive discussion of the factors that can affect fate and transport mechanisms of biosolids in the soil and aquatic environment. The fate and transport characteristics of pathogens and radioactive substances related to biosolids application are described in Chapter 5, “Public Health”.

Environmental Setting

Soils

Soil Properties Relevant to Biosolids Application

The soil properties described below affect the suitability of a site to be used for biosolids application. Some of these properties may change as a result of biosolids application. Additionally, most of the properties are closely related to a site’s productivity with regard to food and fiber crops and livestock forage.

Texture. Probably the most influential soil property relative to land application of biosolids is texture (i.e., the proportions of sand-, silt-, and clay-sized particles in the soil). With other factors held constant, most fine-textured soils (e.g., silty clays and clays) have relatively high capacity to retain nutrients and metals, have moderate available water-holding capacity (i.e., the amount of water that can be taken up by plant roots, measured as inches of water per inch of soil or as the water available throughout the root zone), have slow infiltration capacity and permeability (to gas and water movement), and are relatively difficult to till. The pH (discussed below) of fine-textured soils ranges from near neutral to alkaline. Most clayey soils are fairly resistant to erosion when the vegetation cover is removed, except on steep slopes.

Coarse-textured soils (e.g., loamy sands) generally have relatively low nutrient- and water-holding capacities, have low native fertility, have rapid infiltration capacity and permeability, and are easily tillable. Many coarse-textured soils have low organic matter

content. The pH of coarse-textured soils ranges from near neutral to acidic. Fine-sandy soils are among the soils most subject to water erosion.

Medium-textured soils (e.g., loams and silt loams) usually have fertility and hydrologic characteristics intermediate between those of fine- and coarse-textured soils, although they usually have the highest available water-holding capacity. Medium-textured soils, particularly those with high organic matter content, are generally resistant to erosion on gentle to moderate slopes.

Cation Exchange Capacity. Cation exchange capacity (CEC) is a measure of a soil's net negative charge and thus of the soil's capacity to retain and release cations (i.e., positively charged ions) for uptake by plant roots. Cations (e.g., calcium and ammonium) are often essential for plant growth in small concentrations, but they may be toxic at higher concentrations (e.g., molybdenum, zinc, and copper). Some trace elements such as lead are not required for plant growth but may be toxic to plants and the animals that feed on them. The CEC of a particular soil is controlled primarily by the amount and type of clay mineral in the soil and the humus (highly decomposed organic matter) and iron oxide contents. In coarse-textured soils, humus may provide most of the soil's CEC. For a given quantity (i.e., weight) of soil, the CEC of humus is typically several times that of most pure clays. Clayey soils commonly have a CEC more than five times that of sandy soils. A high CEC is desirable because it reduces or prevents essential nutrient loss from the soil by leaching (Donahue et al. 1983). Soils with high CEC can also immobilize heavy metals such as copper and lead by binding the negatively charged metal anions to cation exchange sites associated with the clay minerals and organic matter.

Organic Matter. Organic matter, another important property of soil, enhances the physical condition of surface soil layers by binding individual soil particles together into larger aggregates (the natural arrangement of soil aggregates provide soil structure). Organic matter particularly benefits the structure of sandy soils. Improved soil structure creates large pores through which gases and water move and which promote root growth. Accordingly, soils with good structure have a lower bulk density and are more permeable than soils with poor structure. A well-aerated, permeable soil is usually more productive than a poorly aerated soil. High permeability improves a soil's infiltration capacity and makes the soil easier to till (Donahue et al. 1983). Furthermore, soils with large, stable aggregates (i.e., well-structured soils) are more resistant to erosion than soils with poor structure (National Academy of Sciences 1996).

Organic matter content also affects the capacity of the soil to retain water and many soluble nutrients and metals, particularly in coarse-textured soils. Organic matter is also the source of most of the nitrogen in an unfertilized soil and can be an appreciable source

of available phosphorus and sulfur. Soil microbes use organic matter as a food source (Donahue et al. 1983).

pH. Soil pH is the measure of the acidity or alkalinity (the amount of hydrogen ion) of a soil. Nearly all California soils have a pH in the range of 5.0-8.5; a pH of 7.0 is considered neutral. Soils with a low pH (i.e., less than 5.5) are acidic and may have lower nutrient concentrations and less microbial activity (Tucker et al. 1987). In strongly acidic soils, bacteria that decompose organic matter and therefore release nitrogen and other nutrients for plant growth are less active. In addition, most heavy metals and some nutrients are soluble, and aluminum and manganese may be present at toxic concentrations. Soil pH also greatly affects the solubility of minerals and many heavy metals, and therefore affects their availability for plant growth and uptake in biomass and their potential to be leached from the soil profile. A slightly acidic soil (e.g., pH 6.5) is typically best for many agricultural crops because macronutrients and micronutrients are overall most available for plant uptake under slightly acidic conditions (Donahue et al. 1983). Maintaining neutral to slightly alkaline soils is often recommended in places where high levels of heavy metals are present because the metals tend to be less mobile at these pH conditions.

Salinity. Salinity refers to the salt content of a soil. Salts are dissolved mineral substances, including sulfates, chlorides, carbonates, and bicarbonates, which may form from the elements sodium, calcium, magnesium, and potassium. Although a low level of salts in the soil is desirable, high salinity levels (commonly above an electrical conductivity of 4 deciSiemens per meter for many crops) make it more difficult for plant roots to extract water from the soil, which may reduce growth rates. (Donahue et al. 1983.)

Bulk Density. Bulk density is a measure of the mass of dry soil per unit volume. It is usually expressed in terms of grams per cubic centimeter. Bulk density affects permeability and root penetration and is affected by texture, structure, organic matter content, and soil management practices. (Donahue et al. 1983.)

Depth. Soil depth affects the capacity of a soil to retain nutrients and metals. References to soil depth pertain to the depth of a soil over rock or a restrictive layer that prevents significant root penetration, such as a hardpan or dense claypan. (U.S. Department of Agriculture 1993.)

Microorganisms. Soil microorganisms, including bacteria, actinomycetes, fungi, algae, and protozoa, play an important role in the decomposition of organic matter, including that contained in biosolids (Phung et al. 1978), and in the cycling of plant nutrients such as nitrogen, phosphorus, and sulfur (National Academy of Sciences 1996). Some evidence indicates that the rate of decomposition of organic matter by

microorganisms may be reduced in the presence of high concentrations of heavy metals (Sommers et al. 1976).

Drainage. A soil's drainage class is determined primarily by its permeability, depth of the seasonal high water table, and slope. At the dry end of the drainage spectrum, soils that are excessively drained tend to be coarse textured, not influenced by high groundwater, and located on steep slopes. Soils that are poorly drained typically have groundwater at or near the surface for much of the crop-growing season and are in level areas and topographic depressions (U.S. Department of Agriculture 1993).

Water and Wind Erodibility. Soils that are highly susceptible to detachment and entrainment (i.e., erosion) by water and wind are those made up mostly of coarse silt and fine sand-sized particles (Donahue et al. 1983), particularly in areas where organic matter content is low and the soil structure is poor or nonexistent. Erodibility is usually a characteristic of concern when the vegetative cover is removed or reduced or the soil is otherwise disturbed. Water erosion typically is not a major concern on gentle slopes (e.g., 10% or less, as generally used for biosolids application) because little rainfall runoff results at such slopes. Erosion is usually controlled by maintaining vegetative cover.

The erosion rate of a particular soil in the absence of human activities is referred to as the natural or geologic erosion rate. Erosion in excess of the natural erosion rate is called accelerated erosion and is usually a result of human-caused activities such as cultivation, grazing, and grading.

Generalized Descriptions of Soil Properties

Soils in California are extremely variable and reflect the diverse geologic, topographic, climatic, and vegetative conditions that influence soil formation and composition. Broad generalizations can be made of soil properties in each RWQCB region which may influence or be influenced by biosolids application, and these are tabulated in Appendix D (Table D-1). Major Land Resource Areas (MLRAs), as classified by the U.S. Natural Resources Conservation Service (NRCS), are large areas that are broadly similar with respect to soils, geology, climate, water resources, and land use. Sixteen MLRAs have been designated in California. MLRA information is appropriate for statewide resource description and planning. Because biosolids are nearly always applied on moderate to shallow slopes (i.e., a maximum of approximately 15%), only soils occurring in valleys, basins, terraces, and alluvial fans are described in Appendix D. Soils occurring in large geographic areas that have been excluded from the GO (i.e., the Sacramento-San Joaquin River Delta, Suisun Marsh, and the jurisdiction of the San Francisco Bay Conservation and Development Commission) are also not described.

Typical Soil Properties in Forested Areas. Soil properties in forested areas of the state that are suitable for biosolids application (i.e., have slopes no greater than approximately 15%) differ from soils typically used for agricultural land application in that they are generally shallow and underlain by bedrock. Forest soils in California tend to have neutral to acidic pH. The organic matter content ranges from relatively low to high (for mineral soils) but is usually concentrated in the upper soil layers. A layer of plant litter often rests on the soil surface. Forest soils are often more thoroughly leached of nutrients than agricultural soils. The texture typically ranges from clay loam to sandy loam, and the soils often have rock fragments in the profile. Except in meadows (which typically would be excluded from biosolids application because they may qualify as jurisdictional wetlands) and seep areas, groundwater tends to be deep. (Colwell 1979, U.S. Soil Conservation Service 1981.)

Typical Soil Properties at Mined Sites. Conditions at mined sites differ from those at agricultural land application sites in that the native soil material has typically been partially or entirely removed or mixed with less productive subsoil material. Although soil and site conditions may vary widely according to the type of mine, the soil materials at such sites often have low nutrient- and water-holding capacities, a large amount of rock fragments, low organic matter content, low pH, and high concentrations of trace metals. These conditions result in unfavorable conditions for seed germination and plant growth, making revegetation efforts difficult (Reed and Crites 1984). Slopes may be steep at some mined sites.

Typical Soil Requirements of Horticultural Operations. In California, biosolids are not used extensively for horticultural plantings. It is expected that the most frequent uses would be in large parkland or golf course settings, or at large-scale nursery operations. These settings could occur throughout the state, but would likely be focused in valley or low foothill areas with relatively deep soils, moderate to shallow slopes (less than 15%), and a wide range of soil textures (loams to clays). Because horticultural areas are usually selected for their ability to support some type of planted vegetation, they would be expected to have low to medium organic matter content, be well drained, and have a pH from slightly alkaline to slightly acidic. Soil conditions that would be unfavorable for seed germination and plant growth would be avoided. Where new parks or golf courses are being developed, biosolids may be applied to soil material imported from offsite. These soils may have little or no remaining soil structure.

Hydrology

Surface Water

The surface waters of California can be divided into six regions of similar hydrologic character, established by the California Department of Water Resources (1994a), that exhibit distinct precipitation, runoff, and geologic conditions. Vast differences in climate, vegetation, and geography between these regions lead to extremes in seasonal patterns, precipitation, and runoff potential throughout the state. The North Coast region, for example, can receive up to 200 inches of rainfall per year, whereas the Colorado Desert region in the southern part of the state receives the least annual rainfall, with some areas averaging less than 2 inches per year (Mount 1995). These patterns, combined with other regional factors, determine the amount and type of runoff emanating from the area, the rate of deep percolation and aquifer recharge, and the potential for flooding. Table 3-1 shows the seasonal patterns, precipitation, and runoff characteristics of the six regions.

Groundwater

Approximately 40% of the total land area of the state is underlain by groundwater basins. The storage capacity of these basins is estimated to be approximately 1.3 billion acre-feet of water, and many of the basins are estimated to be full or nearly full. The fraction of water that is usable from these basins, about 143 million acre-feet, is more than three times the total capacity of the state's surface storage reservoirs.

Many of California's groundwater basins are located in arid valleys and are recharged by percolation of rainfall and surface water flows. Recharge occurs more readily in areas of coarse sediments, which are usually located near the alluvial fans associated with mountain ranges. Percolation in southern California occurs only during periods of intense precipitation, whereas northern California groundwater basins often receive direct recharge from precipitation on an annual basis (California Department of Water Resources 1975). The location and extent of impermeable, confining layers in the alluvial deposits that contain groundwater basins play a major role in the amount and rate of recharge of percolating water and the overall quality of the groundwater.

About 250 important groundwater basins are present throughout California, supplying about 40% of the state's applied water needs. Statewide, more than 15 million acre-feet of groundwater are extracted for agricultural, municipal, and industrial uses. Table 3-2 lists California's major groundwater basins by region.

Table 3-1.
Watershed Characteristics of California

Region	Seasonal Patterns	Runoff Characteristics	Precipitation
North Coast (Region 1)	Inland - distinct rainy, cool winters and hot, dry summers. Coastal - cool and wet year round with little temperature variation.	Highest peak discharges recorded in state, with highest total sediment yields.	Dominated by rainfall. Average annual precipitation in region is 53 inches.
Sacramento, San Joaquin and Tulare Lake (Region 5)	Valley: Hot, dry summers and cool, wet winters. Mountains: Mild summers with intermittent thundershowers, heavy winter snowfalls above 5000 feet.	Prolonged spring runoff fed by Sierra Nevada snowpack. Low sediment yields due to widespread vegetation and stable rock types/soils. Locally high sediment yields due to land uses (e.g., logging, grazing, and urbanization).	Valleys receive winter rainfall, and mountains receive moderate to heavy snowfall. Total average annual precipitation ranges from 36 inches in the Sacramento River region to 13-14 inches for the San Joaquin and Tulare Lake regions.
San Francisco Bay and Central Coast (Regions 2 and 3)	Coast: Cool and foggy year-round with rain in the winter. Small seasonal temperature variations. Inland areas: Warmer, dry summers with cooler, rainy winters.	High peak runoffs due small, steep watersheds. Local rivers susceptible to severe flooding during high rainfall events. Some watersheds produce high sediment yields due to unstable rock types/soils.	Precipitation from rainfall, with insignificant snowfall. Northern area average annual precipitation is 31 inches, with greater than 50 inches in some areas. Southern area average annual precipitation is 20 inches.
North and South Lahontan (Region 6)	Valleys: Semi-arid high desert terrain. Hot, dry summers with locally intense thunderstorms. Mild, dry winters. Mountains: Cool to mild summers, cold winters with regionally heavy snowfall.	Valleys: High peak runoffs in ephemeral drainages. Watersheds except Owens River are short and steep ephemeral drainages. Stable rock types/soils result in low, coarse-textured sediment yields. Mountains: Extended spring runoff with locally high sediment yields in Sierra.	Valleys: Low to moderate precipitation totals due to rainshadow effects of Sierra Nevada and Cascade Mountains. Mountains: Regionally heavy winter snowfall and intense summer thunderstorms. Average annual precipitation ranges from 8 inches in the south to 32 inches in the north.
South Coast (Regions 4, 8, and 9)	Mediterranean climate with several dry years interrupted by infrequent high precipitation years. Warm, dry summers and mild, wet winters. Inland summer temperatures can exceed 90 degrees. Intense subtropical storms.	Watersheds are largely ephemeral and fed by rainfall. Rivers susceptible to frequent flooding due to high peak discharge events. Sediment yields are locally high due to intense urbanization, low vegetation cover and unstable soils. Debris flows and mudflows frequent in some smaller drainages.	High rainfall with insignificant snowfall contribution. Locally heavy storms have the highest 24-hour rainfall totals in the state. Average annual precipitation is 18.5 inches.
Colorado Desert (Region 7)	Arid desert region with hot, dry summers with locally intense thunderstorms and mild winters. Rainfall is limited to a few storms per year.	Low runoff due to limited rainfall, but locally heavy during infrequent storm events. Overall sediment yields are low, but produce debris flows during storms.	All precipitation fall in the form of rain. Region has the lowest yearly precipitation totals in the state, with some areas receiving less than 2 inches. Average annual regional rainfall is 5.5 inches.

Sources: Mount (1995), California Department of Water Resources (1994a), Regional Water Quality Control Board Water Quality Control Plans (1991-1995).

Table 3-2.
Major Groundwater Basins of California

Region	Major Groundwater Basins	Extraction (ac-ft/yr)
1 - North Coast	Tule Lake, Siskiyou Butte Valley, Shasta Valley, Scott River Valley, Hoopa Valley, Smith River Plain, Mad River Valley, Eureka Plain, Eel River Basin, Covelo Round Valley, Mendocino County	242,338
2 - San Francisco Bay	Petaluma Valley, Napa-Sonoma Valley, Suisun-Fairfield Valley, Santa Clara Valley, Livermore Valley, Marin County, San Mateo County	190,128
3 - Central Coast	Soquel Aptos, Pajaro Basin, Salinas Basin, S. Santa Clara - Hollister, Carmel Valley-Seaside, Arroyo Grande/Nipomo Mesa, Cuyama Valley, San Antonio, Santa Ynez Valley, South Central Coast, Upper Salinas, San Luis Obispo	1,075,800
4 - Los Angeles	Central Basin, West Coast Basin, San Fernando Valley, Raymond Basin, San Gabriel, Upper Ojai Valley, Fox Canyon	808,000
5 - Central Valley	Butte County, Colusa County, Tehama County, Glenn County, Sacramento County, Western Placer County, Yuba County, Sutter County, Eastern Solano County, Yolo County, Sierra Valley, Goose Lake Basin, Big Valley, Fall River Valley, Redding Basin, Almanor Lake Basin, Upper Lake Basin, Lake County/Scotts Valley, Kelseyville, Valley Basin, Coyote Valley, Middletown-Colalyomi Valley, San Joaquin County, Modesto Basin, Turlock Basin, Merced Basin, Chowchilla Basin, Madera Basin, Delta Mendota, Kings Basin, Tulare Lake Basin, Kaweah Basin, Tule Basin, Westside Basin, Pleasant Valley Basin, Kern County Basin	8,302,100
6 - Lahontan	Surprise Valley, Honey Lake Valley, Long Valley Basin, Thermo-Madeline Plains, Willow Creek Valley, Secret Valley, Owens Valley, Death Valley, Mojave River Valley, Antelope Valley	397,200
7 - Colorado River	Warren Valley, Coachella Valley, Cuckwalla	114,740
8 - Santa Ana	Orange County (also in Region 9), San Bernardino Basin Area, Riverside Basin Areas 1 and 2, Colton Basin	498,180
9 - San Diego	Temecula Valley, San Juan Valley, El Cajon Valley, Sweetwater Valley, Otay Valley, Warner Valley, San Luis Ray	34,000 (total does not include Warner Valley or San Luis Rey - extraction rates unknown)

Sources: California Department of Water Resources (1994a), and California Department of Water Resources (1975).

Water Quality

Monitoring for water quality protection purposes is conducted through a variety of federal, state, and local programs. The state evaluates current water quality conditions and prioritizes funding efforts for protection, cleanup, and monitoring programs through the individual water quality assessments that are compiled into the SWRCB Section 305(b) reporting process, which is mandated under the federal Clean Water Act (California State Water Resources Control Board 1996a). The Section 305(b) report includes the Section 303(d) lists, which identify water bodies that do not meet applicable water quality standards or designated beneficial uses that are subject to technology-based controls for waste discharges.

Water quality issues differ depending on the location and type of water resource; the size and extent of the watershed and water resources; the location with respect to potential pollutant sources; seasonal and climatic factors; and many other interacting physical, chemical, and biological processes. Medium to large surface water bodies typically have a large capacity to assimilate waste loads of pollutants because various physical and chemical processes are effective at diluting pollutants or transforming them to less harmful components. Biological processes are especially important because many chemical constituents can be absorbed by plants or animals and removed from the water or metabolized in biological tissues to less harmful substances. Consequently, water quality impairment at a large scale is generally associated with watersheds that have extensive development and receive pollutants from a variety of point and nonpoint sources. Point-source pollution is a discharge that originates in a single location, such as a wastewater treatment plant, landfill, or industrial site. Nonpoint-source discharges are generated over a larger area and result from nonlocalized activities such as urban stormwater runoff; mining, agricultural and forestry activities, residential septic systems, or accidental spills.

Surface Water Quality

Surface water quality depends on seasonal hydrologic pattern, mineral composition of the watershed soils, topography, sources of contaminants, and beneficial uses. During summer low-flow conditions, the surface water quality characteristics of most importance to aquatic life are temperature, dissolved oxygen, turbidity, biostimulatory nutrients (e.g., nitrogen and phosphorus) and nuisance algae growth, and toxic constituents (e.g., un-ionized ammonia and residual chlorine). During the higher streamflow conditions common during winter, water quality is influenced more by stormwater runoff and associated pollutants (e.g., sediment, oil and grease from automobiles and paved areas), nutrients from agricultural fields and livestock boarding areas, and organic litter (e.g.,

leaves and grass clippings). The quality of surface water and groundwater used for domestic, agricultural, and industrial supply are characterized by standards such as total dissolved solids content, turbidity, taste and odor, and levels of toxic contaminants.

The most recent Section 305(b) report indicates that most of the state's surface lakes and reservoirs, rivers and streams, freshwater wetlands, and estuaries only partially support all of their designated beneficial uses. Of the water bodies not supporting all of their uses, a small fraction fail to support one or more designated beneficial uses all the time. For example, 10,838 miles of California's rivers and streams only partially support all beneficial uses; however, only 2,142 miles fail to support one or more beneficial uses all the time. For lakes and reservoirs, approximately 569,000 acres partially support beneficial uses, but only 9,670 fail to support one or more uses all the time. For freshwater wetlands, approximately 107,000 acres partially support beneficial uses, but no wetlands fail to support a beneficial use all the time. The Section 305(b) report also identifies the physical or chemical constituents that cause beneficial uses to not be met. In general, lake and reservoir beneficial uses are impaired predominantly by the presence of noxious weeds, trace metals, pesticides, and taste and odor problems. Rivers and streams are affected by a much larger variety of constituents, including sediment, pathogens, pesticides, and trace metals. Freshwater wetlands are affected primarily by trace metals, salinity, and other trace elements.

Groundwater Quality

Groundwater quality has typically been less of a concern than surface water quality because many of the usable aquifers for domestic consumption have been protected by the overlying soils and geological structures. Impairment of groundwater quality has typically been associated with percolation from landfills, leaking underground storage tanks, and other readily identified sources of pollution. The public attention and regulatory focus of managing and protecting groundwater quality are increasing, however, because nonpoint sources are known to cause widespread impairment of groundwater quality through the introduction of contaminants such as nitrates from septic systems and agricultural fertilizers, large-scale use of pesticides and herbicides, and potential infiltration of hazardous wastes from past land uses. The long-term increase in salt content of groundwater is also a major source of impairment. Increases in salts are primarily a result of subsurface percolation of irrigation water or seawater infiltration. The San Joaquin Valley has large areas of shallow groundwater that have experienced long-term increases in salt concentration as a result of irrigated agriculture. The most recent Section 305(b) report indicates that approximately 20,000 acres of groundwater basins only partially support all beneficial uses; however, only 1,150 acres fail to support one or more beneficial uses all the time. Approximately 24,800 acres of groundwater basins have elevated levels of toxic constituents.

Nitrates in Groundwater and Nitrate-Sensitive Areas. Nitrate contamination of groundwater has been documented throughout California (California State Water Resources Control Board 1988, California Department of Food and Agriculture 1989). Nitrogen is present in groundwater primarily in the nitrate form, although minor amounts of ammonium or nitrite may be present. The California drinking water standard or maximum contaminant level (MCL) is 45 milligrams per liter (mg/l) of nitrate (NO_3). This is approximately the equivalent of the state and federal drinking water standard, 10 mg/l of nitrate expressed as nitrogen (N).

Potential sources of nitrate contamination include human and animal waste and large-scale use of nitrogen-based fertilizers. Potential groundwater contamination from nitrates is related to soil characteristics, crop type, irrigation practices, timing and application of nitrogen, geology, climate, and hydrologic conditions. It is difficult to determine whether an observed level of nitrates in groundwater is a result of current or past operations. It is also difficult to quantify the level of nitrate contribution from each potential source (e.g., agricultural, animal waste, septic, or wastewater sources). The most recent statewide assessment of nitrate conditions in groundwater by geographic area in California was produced in 1988 (California State Water Resources Control Board 1988). In general, the data and research available suggest that the potential for subsurface transfer to groundwater of surface-applied nitrogen is highest in highly permeable, sandy soils with low organic matter content under heavy irrigation, and that shallow wells are extremely susceptible. Areas that do not receive a large amount of freshwater recharge also may act as “sinks” and be more susceptible to cumulative loading of nitrates.

The California Department of Food and Agriculture (DFA) has developed criteria for evaluating nitrate-sensitive areas to prioritize funding and research on nitrates (California Department of Food and Agriculture 1998). Soil scientists with the University of California and DFA’s Fertilizer Research and Education Program (FREP) identified seven criteria with which to determine the nitrate sensitivity of an area:

- g Groundwater use**—Nitrate concentration is critically important if groundwater is used for domestic or animal drinking supplies.
- g Soil properties**—Sandy or otherwise coarse-textured soils transmit water containing dissolved nitrates downward more rapidly. Also, these soils are less likely to provide the conditions under which nitrate turns to a gas and escapes from the soil (denitrification).
- g Irrigation practices**—Inefficient irrigation systems that lead to large volumes of subsurface drainage increase the leaching of nitrates. Typically, these are surface-flow systems with long irrigation runs. Well-managed sprinkler or drip

systems, or surface-flow systems with short runs, reduce the risk of nitrates leaching to groundwater.

- g Type of crop**—Crop types most likely to increase nitrate leaching are those that (1) need heavy nitrogen fertilization and frequent irrigation; (2) have high economic value, so that the cost of fertilizer is relatively small compared to revenue produced; (3) are not harmed by excess nitrogen; and (4) take up only a small fraction of the nitrogen applied. Many vegetable, fruit, nut, and nursery crops fit these criteria, and therefore have high potential for nitrate leaching. Crops with lower potential include field crops such as alfalfa, wheat, and sugar beets.
- g Climate**—High total rainfall, concentrated heavy rains, and mild temperatures lead to extensive leaching of nitrates.
- g Distance from the root zone to groundwater**—Small distance from the root zone to groundwater indicates that leaching, if it occurs, will be a more immediate problem.
- g Potential impact**—Such factors as population density and availability of an alternate water supply indicate that nitrate leaching is a potential impact in an area.

The focus of FREP field activities has been established on the basis of these criteria. In general, two regions of the state, the Central Coast valleys and parts of the east side of the Central Valley, fit the above criteria.

Mobility, Bioavailability, and Potential Toxicity of Plant Nutrients and Trace Elements in Biosolids

Several closely related issues are associated with the occurrence of nutrients, trace metals, and synthetic organic compounds in biosolids. The evaluation of what happens to these compounds in the soil, how their presence may affect agricultural productivity and sustainability, how they change and move through soil (to be taken up by plants and grazing animals and ultimately enter the human food chain), and how they are removed from the immediate land application site as soil dust, as eroded particles, or with surface runoff and groundwater flow, is termed a fate and transport analysis.

Most elements present in soil and taken up by plants (including nutrients and toxic metals) must be dissolved in soil water (called the solution phase) to be recovered by plant roots and incorporated into the root mass or aboveground plant biomass. Once absorbed,

elements may be preferentially concentrated in certain parts of the plant (e.g., leaf, petiole, flower, seed, fruit). Where preferential concentrations greatly exceed background soil levels, the compounds are said to bioaccumulate. Elements contained in biosolids are released into the solution phase by microbial decomposition of organic matter containing the elements and by various physical and chemical processes. For this discussion, elements (aside from pathogens, which are discussed in Chapter 5, “Public Health”) that are contained in biosolids and released following application during the subsequent decomposition can be placed into three broad groups:

- g Major elements and plant nutrients** (including nitrogen, phosphorus, and potassium)—These and other elements, such as calcium and magnesium, are generally fairly soluble, occur naturally in soils in relatively large amounts, and are required for plant growth in moderate to large amounts.
- g Trace elements and heavy metals**—These occur in biosolids primarily in small quantities and, when released, often form sparingly soluble reaction products. Some trace elements are required for plant growth, whereas other heavy metals may be toxic to plants.
- g Potentially harmful synthetic organic compounds**—These typically are present in biosolids in small amounts and are generally not taken up by plants. The principal concerns with these compounds are ingestion of plants coated with dust from biosolids sources that are unusually high in synthetic organic compounds and direct biosolid ingestion by grazing animals.

Surface Water Runoff and Groundwater Leaching

Two of the fate and transport pathways evaluated in the Part 503 risk assessment process for land application of biosolids were surface water runoff (pathway 12) and leaching of pollutants to groundwater (pathway 14). Surface water runoff from application sites can occur when rainfall exceeds the infiltration capacity of the soil. Infiltration is influenced primarily by the texture of the soil and the amount of water already stored in the soil. Runoff from application sites may cause accelerated soil erosion and transport of either dissolved or suspended contaminants into surface water bodies.

Leachate is water from either natural precipitation or irrigation that is transported through the soil. Some potential contaminants are soluble in water and may be transported in dissolved forms through the soils. Dissolved contaminants may then move through the soil and percolate to groundwater. Complex biological, chemical, and physical processes govern how water moves through saturated and unsaturated, porous materials.

Major Elements and Plant Nutrients in Soil

Major plant nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium are typically present in moderate amounts in biosolids; however, their total content, mobility in the soil, and bioavailability can vary widely. In addition, biosolids can contain low to moderate levels of soluble salts.

Nitrogen may be present as organic nitrogen, ammonium, nitrate, and nitrite ions. The transformation processes within the nitrogen cycle are biologically and chemically controlled and include volatilization and biological fixation, mineralization, nitrification, and denitrification. With respect to nitrogen content, biosolids are approximately comparable to barnyard manure, and thus provide a source of low-grade, slow- to moderate-release nitrogen. Biosolids contain 1%-6% total nitrogen as measured by dry weight (National Academy of Sciences 1996). Commercial fertilizers contain 11%-82% total nitrogen. Phosphorus is present in both organic and inorganic forms in biosolids, typically at 0.8%-6.1%. Inorganic forms of phosphorus are relatively insoluble, and phosphorus tends to concentrate in the organic and inorganic solid phases.

Organic forms of nitrogen generally predominate in biosolids and must be converted to inorganic forms by the microbial process of mineralization before they can be used by plants. Nitrogen mineralization rates vary as a function of the organic nitrogen content of the biosolids, soil, and climatic conditions; complete mineralization can take 1-5 years, depending on application rates and site conditions. A smaller percentage of total nitrogen is in the form of gaseous ammonia or dissolved ammonium. Immobilization is the conversion of mineral forms of nitrogen to organic forms. Nitrogen can be stored in soil through binding to cation exchange sites, immobilization by soil microorganisms, or absorption and accumulation in biomass. The ability to store nitrogen as ammonium on cation exchange sites is dependent on the CEC level and soil pH. Dissolved ammonium is converted to nitrite and then to nitrate. Nitrate is highly soluble, biologically available, and chemically stable and is either absorbed into biomass, lost to leaching, or converted to nitrogen gas under anoxic conditions.

In addition to the amount of available nitrogen, another important factor in soil management is the relative quantities of nitrogen and various other nutrients (e.g., nitrogen and phosphorus, nitrogen and carbon). Phosphorus is typically present in biosolids in low to moderate amounts, and organic forms must be mineralized to biologically available forms. The relative proportions of nitrogen and phosphorus are as important in plant nutrition management as the total amounts. If nitrogen in the soil is a limiting factor in plant growth relative to phosphorus, then the relative excess of phosphorus may accumulate in the soil and be subject to erosion and leaching, which could affect surface water and groundwater. This usually is not a significant concern in

most native California agricultural soils, which are generally deficient in both phosphorus and nitrogen. In most California soils, phosphorus is tied up in various chemical forms and is only lost from the soil when it is attached to soil particles entrained by runoff. Phosphorus deficiency in plants can reduce plant growth or affect quality and yield. Similarly, biosolids that are high in carbon but relatively low in nitrogen can induce nitrogen deficiency because soil microorganisms have insufficient soil nitrogen available to fuel their decomposition of the organic matter in the biosolids. Nitrogen deficiency is a rare phenomenon in California. If recognized early, these situations can be remedied by application of commercial fertilizers to bring the carbon:nitrogen or nitrogen:phosphorus ratio into balance with crop needs.

Transport Mechanisms of Plant Nutrients to Surface Water and Groundwater. Biosolids application rates are typically dictated by the nitrogen content of the biosolids relative to crop needs, which raises the concern that overapplication may result in the excess nitrogen leaching to groundwater and possibly degrading water quality. Nitrates are difficult to remove from potential sources of drinking water, and both water and fertility must be managed carefully to prevent leaching of nitrates. The total amount of nitrate leaching depends on the amount of nitrate dissolved in the soil-water profile, the volume of water percolating per unit time, and the rate of nitrogen uptake by plants. Once out of the root zone, further movement is governed by complex flow and transport mechanisms, and nitrates may take many years to reach saturated groundwater aquifers (University of California 1995). The nitrate concentration in groundwater is influenced by freshwater recharge and dispersion, both of which may help to reduce contaminant concentrations. Nitrates in groundwater do not impair agricultural beneficial uses of water but may impair the water's usefulness for municipal and domestic purposes.

Runoff of biostimulatory nutrients (nitrogen and phosphorus) may result in eutrophication in receiving waters. Eutrophication is the process by which nutrients increase biological productivity and cause nuisance conditions such as algae scum formation, attached filamentous algae growth on rocks, and excessive growth of vascular emergent and submerged aquatic plants. Increased algae and plant growth can alter the biological system by altering dissolved oxygen and pH conditions in the water or reducing fish habitat. Biosolids application techniques (surface application or incorporation into the soil, with or without tilling), total application rates, seasonal weather patterns, ambient soil moisture, and the duration and intensity of rainfall all influence the potential for runoff to mobilize nutrients in biosolids (Northwest Biosolids Management Association 1998). Liquid biosolids have much greater concentrations of the mobile mineral forms of nitrogen and phosphorus than do the dewatered biosolids. Studies of application of liquid biosolids to a watershed have found little or no impact on stream water quality with respect to nitrogen and phosphorus levels. The application of dewatered biosolids would probably

have no significant impact on the quality of water emanating from watersheds in which dewatered biosolids are applied.

Trace Elements and Heavy Metals

Trace Elements and Heavy Metals in Soil. Trace metals and trace elements are chemical elements that are normally present in the environment in very low concentrations. In small quantities, many elements are essential to plant growth, including fluoride, silicon, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, silicon, selenium, molybdenum, tin, and boron. At higher concentrations, some of these elements may become toxic to plants or accumulate in plants at levels that are toxic to the animals that feed on them (McBride 1984, Dragun 1988, Davies 1980, Kabata-Pendias 1984). In some cases, the range in concentration between deficiency and toxicity is narrow, as is the case with boron. In several cases, there is no known biological necessity for the trace metal, and its occurrence in small quantities in the soil solution may be harmful to plants. Lead, cadmium, and arsenic are examples of this effect. In other instances, such as with molybdenum, there is little or no plant toxicity at elevated soil levels, but grazing animals can be adversely affected if the element is present at high levels in plant forage. Plants can vary widely in their sensitivity to trace element concentrations in the deficiency or toxicity range, their capability to absorb trace elements, and their ability to avoid uptake even at high soil-water concentrations.

Trace metals may behave differently compared to more common soluble salts and plant nutrients in soils. Soil clay content, CEC, organic matter content, oxidation/reduction state, and pH all influence the mobility and bioavailability of metals and nutrients in the soil to varying degrees. The concentrations of major elements and trace metals in the solution phase of the soil-water-plant system are governed by reactions such as acid-base equilibrium, chelation (i.e., a process that binds and stabilizes metallic ions), precipitation and dissolution of solids of oxides and carbonates, and ion exchange-adsorption on clay minerals. Unlike soluble salts, most metallic compounds are not readily soluble in water or very mobile in the soil, except at the low pH levels present in strongly acidic soils. Because of their affinity to soil particles, including clay, organic colloids, carbonates, and iron complexes, trace metals are often retained in the soil and normally do not move readily with the soil-water solution.

Arsenic, molybdenum, and cadmium can be mobile in nonacidic soils and, under certain conditions, can accumulate in bioavailable forms and be potentially toxic in low soil-solution concentrations. Boron is also somewhat soluble and mobile, and plants vary widely in their boron phytotoxicity. Boron is naturally present in extremely high concentrations in a small proportion of California soils. The solubility, and hence the mobility and bioavailability, of cadmium, copper, nickel, zinc, and chromium compounds

are significantly pH-dependent. These metals are associated with iron and manganese hydrous oxide compounds, the solubility of which increases with decreasing soil pH and/or more chemically reducing conditions. As a result, the poorly drained, acidic conditions that occur in some California soils favor mobilization of metals whereas well-drained, nonsandy, basic (alkaline) to slightly acidic soils immobilize most cationic metals. Lead generally has limited mobility in the soil. In slightly acidic, noncalcareous (i.e., low calcium content) soils, lead generally is not bioavailable; instead, it precipitates out as lead hydroxides or lead polymorphites and, consequently, does not readily reach groundwater. Thus, the process of maintaining suitable soil pH levels, drainage, and organic matter content is extremely important in managing lands to which biosolids have been applied. Phytotoxic effects of trace elements to crops and other plants are also addressed in Chapter 4, "Land Productivity".

The valley bottomland, basin, and low terrace soils in many areas of California, which are rich in organic matter and clay, should rapidly and effectively immobilize metals contained in biosolids through chelation and cation exchange. Of greater concern are soils that are sandy and acidic and have low organic matter; in these soils, metals are easily transformed to be readily bioavailable and water moves freely with little soil interaction. These soil conditions are somewhat rare in California but occur on recently formed sandy, alluvial fan soils associated with the granitic foothills of the southern San Joaquin Valley, in some high mountain valleys, and in parts of San Diego and Monterey Counties. The soils of valley margin foothills, which often are acidic and have low organic matter content, may also be difficult to manage for effective biosolids application. Areas of shallow perched groundwater may also raise management concerns.

In measuring total metals concentrations in soils and biosolids and total loading rates, no distinction is made between plant-available and mobile forms of metals in the soil-water solution. Except in biosolids from cities with large amounts of heavy industry, most biosolids contain low concentrations of trace metals relative to levels that can accumulate and adversely affect soil productivity and agricultural sustainability under normal California soil conditions and loading rates. The low mobility of biosolids-derived metals in typical soil environments has been demonstrated in research conducted by Camobreco et al. (1996) and Dowdy et al. (1991). However, some scientists recommend caution in assessing the potential for adverse soil quality and health effects of poorly designed and poorly managed programs of biosolids land application and of such programs operating where unusual soil conditions and cropping patterns occur (Cornell Waste Management Institute 1999). Annual application rates and the total amount of biosolids that can be applied over the long term may be dictated by the trace element content of the biosolids to be used.

Trace Metals in the Aquatic Environment. The risk assessment procedures used to develop the Part 503 regulations are important factors for the

environmental evaluation of the proposed GO regulation. The following trace metals are identified as priority pollutants by the EPA under federal statutes: antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc. Molybdenum is another trace metal that is of general concern in the regulation of biosolids disposal practices because of its potential for uptake in grazing livestock. The priority pollutant trace metals and molybdenum are known to cause toxicity or otherwise have potential to degrade water resources if present under certain environmental conditions and in sufficient concentrations.

As the metals are transported to lower soil layers, small fractions of metals are partitioned between the soil and water. Several studies have shown that only small fractions of metals move to lower soil layers (Camobreco et al. 1996, Dowdy et al. 1991, Sidle and Kardos 1977, McGrath and Lane 1989). One significant factor that may increase the leachability of metals is the decrease in pH caused by mineralization of biosolids organic matter over time. No conclusive evidence has been found, however, to indicate that decreased pH will increase trace metal leachability. Other studies imply that low pH may be a precursor of high metal mobility leading to groundwater contamination (Wallace and Wallace 1994, Emmerlich et al. 1982, McGrath and Lane 1989).

Part 503 Risk Assessments of Trace Metals for Surface Water and Groundwater Pathways. The Part 503 regulations represent the most current understanding of the risks associated with land application of biosolids and are the basis for the proposed GO. Approximately 200 pollutants were originally evaluated for possible consideration in the Part 503 regulations; the risk assessments for surface water and groundwater pathways were ultimately conducted for seven trace metals (U.S. Environmental Protection Agency 1992). All other trace metals either were not detected in the sewage sludges tested during the 1990 National Sewage Sludge Survey (U.S. Environmental Protection Agency 1990) or were detected at sufficiently low concentrations to warrant no further consideration. Of the 14 pathways evaluated for the Part 503 regulations (surface water was designated pathway 12 and groundwater was designated pathway 14), neither the surface water nor the groundwater pathway was found to be limiting to trace metal concentrations or cumulative loading rates resulting from land application of biosolids. Some of the factors evaluated and assumptions used during the Part 503 development process to set limits on trace metals are controversial among researchers and respondents to the scoping notice for this EIR.

In the 1998 CASA survey of trace metal concentrations in sewage sludges from California (California Association of Sanitation Agencies 1999), average concentrations and variability were below the levels reported from the 1990 National Sewage Sludge Survey (NSSS) (U.S. Environmental Protection Agency 1990). Average concentrations of cadmium, copper, lead, nickel, and zinc in the 1998 CASA data range from 25% to 50% of the 1990 national averages; 1998 CASA averages for arsenic, mercury, and

molybdenum are generally similar to the respective national estimates. Selenium is the only trace metal that has higher average concentrations in the 1998 CASA data than in the 1990 NSSS results. Maximum reported concentrations of copper, mercury, and selenium are the only trace metals in the 1998 CASA survey data that exceed the concentration limits identified under the discharge prohibitions of the proposed GO regulation.

Synthetic Organic Compounds

Synthetic Organic Compounds in Soil. Many SOC's used in industrial, commercial, and household applications can be transported to wastewater treatment plants through the municipal wastewater collection and treatment process and therefore can be present in biosolids. As is the case with nutrients and trace elements, the SOC content of the biosolids is determined by the type of business and industry within the wastewater treatment service area, any onsite pretreatment conditions, and the effectiveness of the wastewater treatment process. Many of these organic compounds either are volatile, and so are lost during the treatment process, or biodegrade readily during the treatment process, which is designed and managed to foster microbial decomposition. Other volatile compounds are quickly lost to the atmosphere following biosolids incorporation in the soil. For these reasons, the possible presence of volatile organic compounds in biosolids has generally not been of great concern to regulators and the general public.

Various other nonvolatile organic compounds or semivolatile organic compounds (SVOCs) generally are present in low amounts in municipal biosolids. These include plastic-like compounds (phthalates), pesticides, phenols, detergent additives, polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and the group of chlorinated dibenzo-para-dioxin and chlorinated dibenzo-furan compounds that are often cumulatively referred to as dioxins. The Part 503 regulations do not require that biosolids be tested for SOC's; however, the proposed GO monitoring program would require testing of biosolids for PCBs and SVOCs. Upper limits are set by state and federal hazardous materials rules and regulations, with local municipalities enforcing source inspection and pretreatment provisions associated with their wastewater discharge permits. Toxic chemicals such as DDT, chlordane, aldrin, dieldrin, benzo(e)pyrene, and lindane are known to cause cancer, and other compounds (e.g., dioxin; 2,4,5-trichlorophenol; and pentachlorophenol) are known to cause birth defects. Consequently, many SOC's have been prohibited from being used or manufactured in the United States.

Compared to the large amount of detailed information available on trace elements, much less is known about soil accumulation, plant uptake, and concentration mechanisms of SOC's in soils. The knowledge base is much broader for the attenuation, degradation, and

mobility of volatile compounds, pesticides, and PAHs in the soil. The primary exposure pathways for organic compounds are generally understood to be migration to drinking water sources or dispersal as residues and soil dust that accumulate on plant leaves, rather than direct plant uptake. Direct ingestion, either of soil that contains biosolids or of dust on plant parts by grazing animals, is another exposure pathway of concern. Bioaccumulation of these compounds may lead to increased risk factors for human health effects. Potential phytotoxic effects of SOC to crops and other plants are addressed in Chapter 4, "Land Productivity".

Synthetic Organic Compounds in the Aquatic Environment.

More than 100 EPA-designated organic compounds are regulated as priority pollutants through federal and state drinking water standards, ambient surface water quality criteria, and hazardous waste laws. Most of these compounds are generally not detected in biosolids or are present at very low levels (U.S. Environmental Protection Agency 1990).

In general, transport of organic compounds from the solid to the liquid phase of the soil environment is limited for most constituents (U.S. Environmental Protection Agency 1992, Chaney 1990). Demirjian et al. (1987) showed that organic compounds originating from biosolids application were degraded in the soil or were adsorbed in the surface layer. At an application rate of 100 tons per acre, most compounds degraded considerably during one irrigation season. At an application rate of less than 25 tons per acre, most compounds degraded to less than 50% of their initial concentration. The authors concluded that the sandy soils in the study area and the heavy irrigation required for the experiment represented severe conditions for land application and that nutrients and trace metals would be the limiting factors in determining appropriate application rates under average soil conditions (Demirjian et al. 1987).

Alexander (1995) showed that the binding effect that causes toxins to persist in the soil becomes more pronounced the longer the pollutant remains in soil and that higher organic matter content leads to a greater binding effect. The report states that the disappearance of appreciable amounts of insecticides from a field was not a result of leaching because all chemicals were extensively adsorbed to soil particles or organic matter and little vertical movement has been detected, even after many years. As a chemical persists in the soil and remains in contact with particulate matter for an extended period, it becomes increasingly resistant to extraction by many solvents. For example, Rappe et al. (1997) reported that dioxins have extremely low solubility and are unlikely to leach from soil into groundwater.

Part 503 Risk Assessments of Synthetic Organic Compounds for Surface Water and Groundwater Pathways. SOC were included in the original pollutant screening and risk assessments conducted during development of the Part 503 regulations for land application of biosolids. Of

approximately 200 pollutants originally evaluated for possible consideration in the Part 503 regulations, the risk assessments for surface water (pathway 12) and groundwater (pathway 14) were ultimately conducted for 10 priority pollutant organic compounds (U.S. Environmental Protection Agency 1992). Other organic compounds either were not detected in the tested sewage sludges or were detected at sufficiently low concentrations to warrant no further consideration. The groundwater pathway was not found to be the limiting pathway for concentration limits or cumulative loading rates of any organic compounds resulting from land application of biosolids. The surface water pathway (i.e., humans eating fish that have accumulated pollutants from surface runoff) was the limiting pathway for setting limits on DDT/DDE compounds.

Upon completion of the risk assessments for organic compounds, the EPA concluded that regulations for organic compounds were not required for the final Part 503 regulations because each of the compounds met at least one of the following criteria:

- g the pollutant is banned from being used, has restrictions on its use, or is not manufactured in the United States;
- g it was detected in less than 5% of the sludges tested for the 1990 National Sewage Sludge Survey; or
- g the 1-in-10,000 cancer risk limit was less than the 99% maximum probable concentration based on 1990 NSSS data.

Limits were not set for DDT/DDE compounds because they are excluded from all EPA screening criteria. Several organic compounds were deferred for future consideration and evaluation during the second round of regulation development. The organic compounds of interest for future consideration are PCBs, chlorinated dibenzo-para-dioxins, and chlorinated dibenzo-furans (dioxin). Research is also being conducted on other aromatic surfactants (e.g., linear alkylbenzene sulphonates and ethoxylates) that may have hormone-mimicking properties; however, little is known about their means of transport from biosolids application sites (Krogman et al. 1997, Clapp et al. 1994).

Some of the factors and assumptions used during the Part 503 development process to set limits on toxic organic compounds are controversial. The elimination and deferment of Part 503 limits for organic compounds is a source of some controversy among researchers, as indicated by respondents to the scoping notice for this EIR. The primary arguments presented in favor of setting limits on organic compounds in the Part 503 regulations include the following:

- g the elimination process was arbitrary,

- g** the lack of monitoring requirements means that no information is available on which to base application decisions,
- g** the risk assessment does not address risks associated with specific compounds for which supporting research data are lacking, and
- g** groundwater dilution factors identified in the risk assessment may have been too large (Cornell Waste Management Institute 1999).

Comments received during the scoping process indicated a concern that the Part 503 risk assessments may not accurately reflect environmental conditions in California or account for risks from new organic compounds such as pharmaceuticals. General concern was also expressed regarding the assumptions used for the Part 503 regulations regarding synergistic or combined risks from exposure to multiple constituents that may be present in biosolids. EPA contends that the risk assessment process was based on conservative assumptions and that no scientific data have been presented that would invalidate the results of the risk assessments (U.S. Environmental Protection Agency 1995).

Regulatory Setting

Key Policies, Laws, and Programs

Water Quality Regulations and Permits

Numerous policies, laws, and programs are administered by local, state, and federal agencies to enforce limitations on the discharge of pollutants to the environment; maintain surface water and groundwater quality at existing levels; and protect beneficial uses such as municipal, industrial, and agricultural water supply, recreation, and fish and wildlife habitat. Federal, state, and local water quality regulations apply to any chemical constituent contained in biosolids or any activity that would occur as a result of land application of biosolids.

The SWRCB establishes water quality control policies in California in accordance with the State Porter-Cologne Water Quality Control Act and the federal Clean Water Act and implements those policies through nine RWQCB offices. The nine regions were initially established according to similar and unique hydrologic and water quality characteristics. Figure 1-1 shows the names and boundaries of the nine RWQCBs.

Each RWQCB has primary responsibility for designating the beneficial uses of water bodies within its region, establishing water quality objectives for protection of those uses, issuing permits, and conducting enforcement activities. Beneficial uses are defined as those uses of the water resource for which numerical and narrative water quality objectives have been established to prevent water quality impairment. Water quality objectives and associated narrative and numerical water quality objectives are established in a Basin Plan for each region that is updated through a triennial review process. The principal permitting processes administered by the RWQCBs for water quality protection are WDRs imposed on waste discharges to land and water, and permits issued under the NPDES as required by the federal Clean Water Act. WDRs and NPDES permits issued to waste dischargers impose discharge restrictions and pollutant limits that take into consideration applicable state and federal water quality criteria for surface water, groundwater, and drinking water. The permit processes must also consider the state's antidegradation policy, which is intended to protect high-quality waters by setting criteria that must be met before a discharge is allowed that would reduce water quality and yet maintain beneficial uses.

Numerical Water Quality Criteria. Numerical water quality criteria that apply to this program include Basin Plan water quality objectives for surface water and groundwater, state and federal ambient surface water quality criteria, and state and federal drinking water standards. The RWQCBs are required to include effluent limitations on toxic priority pollutants in any WDRs and NPDES permits issued for wastewater discharge to surface waters when the discharge may cause the surface water to exceed established standards for priority pollutants. Regulated priority pollutants include approximately 130 trace metals and organic compounds that are known to be toxic to living organisms when present in water at sufficient concentrations.

Regulations pertaining to priority pollutants have been developed in four main regulations: narrative requirements in the Clean Water Act, the National Toxics Rule (NTR), the rescinded Inland Surface Waters Plan/Enclosed Bays and Estuaries Plan (ISWP/EBEP), and the recently proposed California Toxics Rule (CTR). The proposed CTR was developed in accordance with Section 303(c)(2)(B) of the Clean Water Act (Federal Register Vol. 62, No. 150 - August 5, 1997) to fill the gap in regulation created when the ISWP/EBEP was legally challenged and overturned. The SWRCB subsequently issued a Draft Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California and Accompanying Functional Equivalent Document (California State Water Resources Control Board 1996b) that identifies the proposed rules for using the CTR criteria as a new ISWP/EBEP. Following adoption of the CTR or another form of ISWP/EBEP, wastewater discharges and NPDES-permitted facilities will be required to comply with the new standards for priority pollutants.

Drinking water standards, established by DHS under Title 22 CCR Division 4, Chapter 15 - Domestic Water Quality and Monitoring, apply to groundwater and surface water. EPA has developed similar standards under the federal Safe Drinking Water Act. Both sets of laws contain MCLs that are based on a one-in-a-million (10^{-6}) incremental risk of cancer from ingestion of carcinogenic compounds and threshold toxicity levels for other compounds. The MCLs are also based on technological and economic factors relating to the feasibility of achieving and monitoring the pollutants in a drinking water supply. Secondary MCLs are established for welfare considerations such as taste, odor control, and laundry staining. The MCLs apply primarily to the quality of water after it has entered a distribution system they apply to source water only when specifically established in a region's Basin Plan by the RWQCB.

NPDES Permits. Discharges of waste to surface water bodies, including discharges from wastewater treatment plants (WWTPs), are regulated through the NPDES permitting process, which is mandated under the Clean Water Act. The NPDES permit program regulates ~~for~~ point-source discharges, such as industrial stormwater facilities and WWTPs. The NPDES permit process for WWTPs typically involves the imposition of various chemical, physical, and biological standards on the effluent and receiving water body. Biosolids treatment and disposal regulations can be included in the NPDES permit for the treatment plant or can be covered under separate WDRs.

National Pretreatment Program for Industrial Discharges.

Pretreatment of industrial discharges is mandated by the Clean Water Act of 1977 (33 U.S. Code [USC] Sections 1251-1376; Public Law [P.L.] No. 95-217, 91 Stat. 1566). EPA has established pretreatment standards (40 CFR Part 403) for various industrial categories. EPA created the National Pretreatment Program and first issued pretreatment regulations in November 1973. Following amendment of the Clean Water Act, the regulations were revised in June 1978 and again in January 1981. The purpose of the National Pretreatment Program is to regulate the discharge of pollutants to municipal ~~sanitary~~~~sanitation~~ sewers. The goal is to protect receiving water quality and the environment from pollutants that can pass through a WWTP relatively unaffected by the treatment processes. An individual pretreatment program will typically involve several steps:

- g** identification of pollutants that could cause upset or bypass (pollutants of concern);
- g** development of discharge limitations for nondomestic discharges (local limits);
- g** identification of nondomestic discharge sources; and

g implementation of nondomestic monitoring programs to enforce the local limits.

Source control programs have significantly reduced the biosolids pollutant concentrations. This is shown by the decrease in biosolids pollutant concentrations at facilities with aggressive source control programs. As source control programs are continually being improved because of more stringent pollutant limitations, pollutant concentrations in biosolids will continue to decrease or, at a minimum, remain the same.

Nitrate Management: Research, Technical Support, and Technology Transfer on Agronomic Rates

In 1988, the SWRCB prepared the Nonpoint Source Assessment Report (California State Water Resources Control Board 1988), documenting water quality threats and evaluating programs designed to reduce nonpoint-source pollution. Unlike point sources of contamination that are discreet and subject to regulatory control, nonpoint sources of contamination are typically associated with longstanding and generally acceptable societal practices and land use activities where liability for contamination is hard to determine, and where regulatory programs cannot easily remedy the problem. Agriculture, silviculture, urban stormwater runoff, and grazing are land use activities that have the potential to degrade water quality. The SWRCB has begun to define strategies to deal with nonpoint-source contamination and is developing a watershed management initiative (California State Water Resources Control Board 1995a). The Technical Advisory Committee for Plant and Nutrient Management was convened to assist in developing the Initiatives in Nonpoint Source Management (California State Water Resources Control Board 1995b); these management initiatives respond to nonpoint-source contamination in California. The committee recommended that specific assessments of farming activities be conducted by agricultural experts familiar with unique agronomic conditions and local practices. It was anticipated that these assessments would be used to define appropriate best management practices (BMPs) to control nutrient leaching and make available the best available information and current research.

DFA's FREP program was created to advance the environmentally safe and agronomically sound use and handling of fertilizer materials. The program facilitates and coordinates the development of applied research and demonstration projects that provide technical assistance and funding to carry out research, demonstration, and education projects related to use of nitrogen fertilizers in agriculture. FREP also seeks to improve access to information on agronomic uses of nitrogen and serves as a clearinghouse for data and research. Funding is provided by a tax on agricultural fertilizers. FREP is part of the Nitrate Management Program established by DFA in 1990 to identify nitrate-sensitive areas and reduce the agricultural industry's share of nonpoint-source nitrate contamination. The information and research generated and distributed by FREP will

assist in defining nitrogen agronomic rates for a range of crops and conditions found in California.

The Certified Crop Adviser (CCA) program has been developed by the American Society of Agronomy (ASA) in cooperation with agribusiness retail dealers, cooperatives and manufacturers, state and national trade associations, the U.S. Department of Agriculture (USDA), and independent consultants. The aim of this group is to develop a voluntary program for crop advisers that would establish standards for knowledge, experience, ethical conduct, and continuing education; enhance professionalism; and promote dialogue among those involved in agriculture and natural resource management.

The University of California, California State University, local County Agricultural Extension Service offices, NRCS, and USDA are all actively pursuing projects and research related to nutrient management and agronomic rates of nitrogen for various crop conditions in California. This information is being made widely available through local resource conservation districts, water districts, agricultural organizations, and county agricultural commissioners. These same groups have been conducting research and demonstration projects to evaluate the effectiveness of on-farm BMPs for reducing nitrate contamination.

Drinking Water Source Water Assessment and Protection Program

The DHS Division of Drinking Water and Environmental Management is developing a program to assess the vulnerability of drinking water sources to contamination (California Department of Health Services 1999). This program, which is required by federal and state law, is called the Drinking Water Source Water Assessment and Protection (DWSWAP) Program. The wellhead protection portion of the program has been approved by EPA, and DHS anticipates receiving approval of the surface water component in mid-1999. Completion of drinking water source assessments is required by April 2003. The federal Safe Drinking Water Act requires states to develop a program to assess sources of drinking water and establish protection programs.

California's DWSWAP Program is the first step in the development of a complete drinking water source protection program. The DWSWAP Program will include evaluation of both groundwater and surface water sources. The groundwater DWSWAP program includes components intended to fulfill the requirements for state development of a Wellhead Protection Program strategy, as required by Section 1428 of the Safe Drinking Water Act amendments of 1986. A Wellhead Protection Area (WHPA), as defined by the 1986 amendments, is "the surface and subsurface area surrounding a water well or wellfield supplying a public water system, through which

contaminants are reasonably likely to move toward and reach such water well or wellfield”.

DHS must inventory possible contaminating activities (PCAs) that might lead to the release of microbiological or chemical contaminants within the delineated area. An essential element of the DWSWAP program is an inventory of PCAs that are considered to be potential sources of contamination in the designated drinking water source areas and protection zones. Irrigated agriculture and land application of biosolids are recognized as PCAs. As such, specific setback requirements from municipal and domestic wells and from surface water sources that provide drinking water will be required upon completion of the assessments and vulnerability analyses by DHS or locally responsible agencies. Biosolids application and agricultural applications of fertilizer are classified as having a moderate potential risk of contaminating drinking water (California Department of Health Services 1999).

Groundwater Management Plan (AB 3030)

Sections 10750-10756 of the California Water Code (AB 3030) were signed into law in 1992 and describe components that may be included in a groundwater management plan developed by a local agency to protect groundwater. In all, 149 agencies have adopted groundwater management plans in accordance with AB 3030 (California Department of Water Resources 1994c). Each component would play a role in evaluating or operating a groundwater basin so that groundwater can be managed to maximize the total water supply while protecting groundwater quality. California Department of Water Resources Bulletin 118-80 defines groundwater basin management as including planned use of the basin's yield, storage space, transmission capability, and water in storage (California Department of Water Resources 1975). Ground water basin management includes:

- g** protection of natural recharge and use of intentional recharge,
- g** planned variation in amount and location of pumping over time,
- g** use of groundwater storage conjunctively with surface water from local and imported sources, and
- g** protection and planned maintenance of groundwater quality.

The 12 components listed in Section 10753.7 of the Groundwater Management Act (AB 3030) form a basic list that includes data collection and operation of facilities that may be undertaken by an agency operating under this act. With respect to protecting

groundwater from potential contamination from biosolids, the critical components to be included in local plans include the following:

- g** identification and management of wellhead protection areas and recharge areas,
- g** regulation of the migration of contaminated groundwater,
- g** administration of a well abandonment and destruction program,
- g** monitoring of groundwater levels and storage, and
- g** review of land use plans and coordination with land use planning agencies to assess the risk of groundwater contamination from various activities.

Impacts and Mitigation Measures

Approach and Methods

The evaluation of impacts is supported by the information provided in “Environmental Setting”, which is referred to when necessary to support the impact determinations. The evaluation included a review of the available research and scientific literature used to support the development of the Part 503 requirements and similar documentation from other biosolids application projects. Potential impacts were evaluated based on available data regarding the extent, duration, frequency, and intensity of possible biosolids-related effects on soils, hydrology, and water quality. Impacts that affect land productivity and land classification are described in Chapter 4, “Land Productivity”.

Thresholds of Significance

Adoption of the GO may have a significant impact on soils, surface water, or groundwater if it would:

- g** substantially alter existing drainage patterns of the site or area in a manner that would result in substantial erosion or sedimentation, either onsite or offsite;

- g** substantially alter existing drainage patterns on the site or in the area, resulting in substantial increases in the rate or amount of surface runoff and cause flooding onsite or offsite, or which would contribute runoff water that would exceed the capacity of the existing or planned stormwater drainage system;
- g** increase the demand for surface water or groundwater supplies in areas with existing shortages;
- g** violate RWQCB water quality standards or objectives or cause impairment of beneficial uses of water;
- g** substantially deplete groundwater supplies or interfere with groundwater recharge to such a degree that there would be a net deficit in aquifer volumes or lowering of the local water table.

Impacts of Agricultural Use

Impact: Changes to Existing Drainage Patterns or Increase in Surface Runoff

In many areas of the state, land application of biosolids may have beneficial impacts on soils associated with reduction in runoff as a result of increased infiltration capacity and improvement in soil conditions that reduce the potential for erosion. Biosolids application activities that would occur under the GO would cause negligible alteration of existing drainage patterns or increase in erosion or sedimentation, either onsite or offsite. None of the activities that may occur under adoption of the GO would increase the rate or amount of surface runoff, result in flooding onsite or offsite, or contribute to additional runoff of water exceeding the capacity of existing or planned stormwater drainage systems. The improvements in soil water-holding capacity may reduce water demand in silvicultural, horticultural, or agricultural operations. This impact is considered less than significant.

Mitigation Measures: No mitigation is required.

Impact: Changes in Groundwater Supply and Hydrology

None of the actions anticipated to occur through application of the GO are anticipated to cause increases in demand for groundwater or to alter the rate or direction of

groundwater flow. Improvement of the soil's water-holding capacity may be a beneficial impact and reduce water demand over pre-application conditions at horticultural, silvicultural, reclamation, and agricultural sites. This impact is considered less than significant.

Mitigation Measures: No mitigation is required.

Impact: Potential Degradation of Surface Water from Nutrients in Biosolids

Land application of biosolids has the potential to degrade the quality of surface water, including adjacent streams, lakes, and wetlands, through surface runoff of pollutants from the application sites. Potential mechanisms of contamination from pollutants include the following:

- g** During low-probability rainfall events or accidental overirrigation, surface flow rates could exceed soil infiltration capacities and the capacity of runoff control facilities, resulting in runoff entering surface water less than 30 days after application, in violation of provisions of the GO.
- g** Biosolids being applied to previously uncultivated land could be placed directly into undetected seasonal wetlands (e.g., vernal pools) during the dry season.
- g** Accidents could occur during transport of biosolids, with resulting discharge to surface water.

In California, environmental conditions that could lead to surface water runoff are primarily present in areas with many surface streams and other water bodies. Areas of high winter rainfall, such as the north and central coastal regions and interior northern California, have the greatest potential for rainfall intensities that could exceed the capacity of runoff control facilities. Seasonal wetlands are present throughout the Central Valley and coastal plains, and in these areas careful consideration would be required in selecting locations for biosolids application projects. Accidents related to transport of biosolids might also result in discharge of biosolids to surface waters, but this event would not be expected with sufficient frequency or probability to warrant specific mitigation measures at the programmatic level of analysis.

The proposed GO contains several prohibitions and specifications that would minimize or prevent the occurrence of pollutant runoff for most site-specific conditions in California. The GO prohibits discharges that could cause pollution and further requires that there shall be no discharge of biosolids from the storage or application areas to adjacent land

areas not regulated by the GO, to surface waters, or to surface water drainage courses. The discharger would not be able to apply biosolids directly to surface waters, and GO specifications are consistent with Basin Plan policies for water quality protection. The NOI requires dischargers to provide site-specific information that each RWQCB would use to evaluate whether surface runoff would be prevented. This information includes the site location and map, location of surface waters, types of crops grown, rate of biosolids application, and identification of periods to be avoided to prevent runoff from the biosolids application site. The SWRCB and individual RWQCBs are responsible for reviewing discharger-provided information, evaluating site-specific conditions, and determining whether the biosolids application project under an individual NOI would comply with the minimum standards of the GO.

For the discharger to be able to comply with the GO, appropriate BMPs that meet industry standards and guidelines would have to be implemented that are effective at preventing accelerated erosion and runoff. The discharge of contaminants to surface waters from biosolids application sites can be prevented by controlling offsite runoff, avoiding wet-weather application of biosolids, and incorporating biosolids into the soil after application. The information needed to design and implement a biosolids application project that is in compliance with provisions of the GO is readily available from existing databases; agricultural extension programs; and through the services of knowledgeable agricultural, horticultural, or forestry professionals. As described above, several state and federal agencies maintain databases that provide hydrologic and climatic information.

Minimum standards under the GO that would ensure protection of surface waters from water quality impairment include setback distances from water bodies, requirements to control runoff through limited seasonal periods for application, use of vegetated buffer strips, and preparation of erosion and sediment control plans for steep slopes. Refer to Chapter 8, "Fish", for the discussion regarding potential impacts on fisheries productivity resulting from temporary discharges of suspended solids and sediment. Surface and subsurface runoff of toxic substances could also affect fisheries by causing toxicity to protected species in enclosed water bodies. These specific impacts are not considered significant to water quality, however, and this impact is therefore considered less than significant.

Mitigation Measures: No mitigation is required.

Impact: Potential Degradation of Groundwater from Nutrients

The evaluation of potential impacts on groundwater is focused on nitrate because the GO prohibits biosolids application rates that exceed the agronomic rate of nitrogen uptake by plants. Nitrate is highly soluble in water and chemically stable in the aquatic environment,

and the requirements for applying biosolids at the agronomic rate were established to reduce the available pool of nitrate, which may then be leached and transported to groundwater. The GO defines the agronomic rate as “the nitrogen requirements of the plant needed for optimal growth and production, as cited in professional publications for California, the County Agricultural Commissioner, or recommended by a Certified Agronomist”. This is a conservative standard and is acknowledged to be the limiting factor for determining the total allowable dry-weight application rate of biosolids under typical environmental conditions. The GO prohibitions also state that “the discharge shall not cause or threaten to cause pollution”, which implies that nitrate levels in groundwater must not cause violations of the Safe Drinking Water Act such as exceedance of the 45-mg/l-as- NO_3^- standard at a well providing municipal or domestic drinking water. The potential rate of leaching of other pollutants to groundwater, such as trace metals and SOCs, would be less than the leaching rate for nitrate because those compounds are less soluble and are typically present in lower concentrations relative to their solubility characteristics.

Biosolids applications could provide a net benefit if the nitrogen contribution is factored into the overall on-farm soil, water, and fertility management program. Biosolids have the potential to reduce the reliance on chemical fertilizers. A large fraction of the nitrogen contained in biosolids is bound in an organic form, such that the required mineralization process reduces the rate and quantity of soluble nitrate formation that is then available to leach beyond the root zone. Increased water-holding capacity of the soil by resulting from biosolids application could reduce nitrate leaching. Increases in soil organic matter as a result of biosolids application could improve nutrient cycling and overall soil productivity, and the improved management techniques that may result from consultation with certified crop consultants could reduce cumulative nitrate loading from historic levels.

Even at agronomic rates, however, some leaching of nitrates may occur at biosolids application sites. The potential for leaching of nitrates is closely related to the amount of water that is available to transport dissolved contaminants from the root zone. When water moves out of the root zone, whether as a result of irrigation or as runoff from rainfall during winter fallowing of agricultural land, some nitrate will move out of the biologically active soil zone as a dissolved constituent in the leachate. This could affect groundwater if land application resulted in any of the following conditions:

- g** nitrogen concentrations in biosolids leachate that exceed drinking water standards as a result of:
 - unknown agronomic rate or inaccurate rate calculation (i.e., failure to account for cropping pattern and rotation, timing of biosolids application, total volume of nitrogen applied, rate of mineralization);

- irrigation not being closely managed and water being applied in excess of the soil's water-holding capacity at times when nitrates are available for leaching from the soil;
 - rainfall exceeding the soil's water-holding capacity over the winter or during fallow periods, resulting in nitrates leaching from the soils;
- g** nitrogen concentrations in biosolids leachate that exceed drinking water standards and site-specific evaluations that do not consider local hydrogeology, groundwater assimilative capacity, or vulnerability of municipal and domestic wells; or
- g** nitrogen concentrations in biosolids leachate that exceed drinking water standards and existing groundwater quality that is close to exceeding the drinking water standard, groundwater quality that is unknown and close to exceeding the standard, or a groundwater basin that is internally drained such that there is limited assimilative capacity.

There are several areas in California where the susceptibility to nitrate contamination is particularly severe. Nitrate-impaired basins have been identified by the SWRCB (California State Water Resources Control Board 1988). In areas with high evapotranspiration rates and high dissolved salt concentration of irrigation water, irrigation water is intentionally overapplied to maintain soil productivity. In California, the major areas where irrigation is used for leaching of salts are the Imperial and Coachella Valleys, the southern San Joaquin Valley, Tulare Basin, and other regions of the Central Valley. Winter precipitation on fallow land may also mobilize nitrates in many areas of the state, primarily the coastal communities that receive heavy rainfall, interior areas of northern California that receive heavy rainfall, and forested areas that have large amounts of snow.

Even if nitrate levels in biosolids leachate may exceed the established drinking water standards, the impact of leachate on groundwater would not necessarily be significant if water quality standards in the groundwater are not exceeded and beneficial uses are not impaired. Some nitrate leaching is acceptable if the groundwater assimilative capacity is sufficient to prevent degradation of groundwater quality or if the nitrate concentration in the leachate is less than that in the groundwater. In some areas of the state, the groundwater may not support the beneficial use as domestic supply, in which case the RWQCB is allowed to make site-specific decisions regarding the level of pollution control that is required for a project.

For typical soil and hydrologic conditions present in California, land application of biosolids at agronomic rates of nitrogen uptake has a low probability of impairing groundwater because the GO prohibits biosolids application projects that would cause such degradation

and requires management practices to ensure compliance. The GO also specifies minimum setback requirements from wells and a minimum depth of groundwater at which monitoring would be required. Each RWQCB would have to consider all of the available information and data resources to ensure that general WDRs issued under the GO conform with the prohibitions and do not lead to water quality impairment. The SWRCB and individual RWQCB staff members are required to review discharger-provided information, evaluate site-specific conditions, and determine whether the proposed biosolids application project identified in an individual NOI would comply with the minimum standards of the GO. The databases and regulatory programs described above provide adequate resources for RWQCB engineers to make informed decisions on issuing a notice of applicability (NOA) for the project under the GO or rejecting the application (an NOA indicates that the proposed project can be permitted under the conditions of the GO). Given the full consideration of all available site-specific information for a proposed land application project, as specified in the NOI, and of other supplemental information and resources available to the RWQCB engineer, the RWQCB would not issue an NOA for the project if it could not ensure that the application project would comply with the GO.

As described above, various resources and programs are available with which to determine whether a project would result in violations of minimum standards specified in the GO. The SWRCB recognizes that individually prescribed fertilizer management practices should be specific to the unique crops, soils, and the potential risks to groundwater (California State Water Resources Control Board 1994).

The calculation of agronomic nitrogen uptake rates is becoming more fully integrated with complete farm fertility programs, and more environmental data are available to be used by certified crop advisors, agricultural engineers, agronomists, and other professionals in developing agronomic rates specific to local conditions and crop types. Agricultural water management plans required by state and federal programs have also been developed throughout the state and are intended to improve water conservation and reduce water demands. Farmland water management occurring as a result of these plans will also serve to reduce deep percolation of irrigation applied water and the potential for leaching of nitrates and other potential contaminants. Farm-level plans are currently not required in many areas of California. Several state and federal agencies maintain databases that provide real-time hydrologic and climatic information for optimal management of farm irrigation systems. This information is being made widely available through the agricultural industry by County Agricultural Commissioners, Agricultural Cooperative Extension, local water districts, resource conservation districts, and other state and federal agencies and as a result of the other programs described in the settings sections. The voluntary implementation of BMPs is being promoted as a means of reducing agrochemical contamination (California State Water Resources Control Board 1995b).

The activities to be undertaken as part of DHS's implementation of the DWSWAP Program, described above, will result in development of wellhead protection zones to protect groundwater and assess the vulnerability of municipal and domestic drinking water supplies that serve more than two service connections. (Single-connection residential wells are not part of the program.) The wellhead protection portion of the DWSWAP Program will include specific groundwater vulnerability analysis of all possible contaminating activities, including biosolids. In addition, local AB 3030 plans that characterize the local hydrogeology or have established wellhead protection programs and local requirements will also provide some assurance that groundwater assimilative capacities will not be exceeded. This impact is considered less than significant.

Mitigation Measures: No mitigation is required.

Impact: Potential Degradation of Surface Water and Groundwater from Trace Elements in Biosolids

Biosolids application to land has the potential to contribute to surface runoff or to leachate beyond the plant root zone trace metals and other elements that could eventually reach groundwater. For water quality impacts to occur, the concentrations in surface runoff or subsurface leachate would have to exceed applicable regulatory water quality criteria (the lower of either ambient water quality criteria for aquatic life, human health from consumption of organisms, or drinking water standards) and result in toxic effects on the aquatic environment or impair beneficial uses of the water.

The GO contains numerous minimum standards that the discharger must implement to control surface water runoff from the application site. As described above, the potential for surface water runoff of biosolids is low because provisions of the GO would require dischargers to implement appropriate BMPs, such as maintaining minimum setback distances from surface waters and wells, prohibiting application directly to surface waters, prohibiting application to saturated or frozen ground or areas subject to washout, preventing runoff for the period within 30 days of application, and requiring that an erosion control plan be professionally prepared for areas with slopes greater than 10%. Consequently, the probability of washout is substantially reduced because biosolids application projects would have to be designed to meet the runoff prohibitions.

Potential impacts on groundwater quality were evaluated based on information developed for the Part 503 risk assessment process and other available data. The risk factors for increased leaching of trace metals from biosolids into groundwater increase under extreme soil pH conditions, high concentrations of trace metals in the biosolids or soil, and hydrologic conditions such as high rainfall or presence of shallow groundwater. In some areas in California, as described above, one or more risk factors are higher than under

typical conditions statewide. Low soil pH can exist in such areas as reclamation sites where acid drainage is present, some forest soils, and isolated regions of the Monterey and San Diego coastal regions. Some areas of the state have naturally high background concentrations of trace elements in the soil, such as selenium and boron in some southern San Joaquin Valley areas. Historical mine sites also may have high background levels of trace elements such as copper, zinc, mercury, lead, and cadmium, such as in northern California.

The potential impact of trace metals on groundwater quality is considered less than significant based on the regulatory performance standards established under the GO, operational requirements for a discharger applying biosolids under the GO, or naturally occurring conditions that would result in low probabilities for water quality impairment. The following list describes types of impact mechanisms and mitigating factors and/or protections provided under the GO to reduce the potential impacts:

- g** Cultivated California soils generally have a neutral to alkaline pH (Holmgren et al. 1993), which thereby reduces the potential for trace metal mobility to the soluble phase. Over time, soil pH may become lower as a result of biosolids application, but there is no evidence that this condition increases metal mobility in soil. Low soil pH is a factor that needs to be considered by each RWQCB when evaluating proposed biosolids application projects. Each potential discharger would be required to submit soil pH data, and the RWQCB would evaluate the data for mine reclamation sites where pH conditions may be low as a result of acidic drainage water from mines. Some forest soils may also have lower pH than agricultural soils. RWQCB engineers would evaluate the information provided in each discharger's NOI to determine whether the application project is consistent with the GO prohibitions.
- g** The Part 503 risk assessment process for 14 contaminant pathways determined that the surface water and groundwater pathways were not limiting to any of the allowable trace metal concentrations or cumulative loading limits. The limiting pathway is the transport route for the contaminant in the environment that poses the lowest acceptable risk for application of biosolids to land. The risk assessments were conducted to evaluate risks from long-term application every year for 100 years as well as the risks associated with the total amount of metals that would build up in the soil after continuous application. Because biosolids applied under the GO would be tested for heavy metals, land application of biosolids for the entire 15-year period of the GO has a very low probability of exceeding risk thresholds for surface water and groundwater pathways that were developed using models that assumed application would continue for 100 years.

- g The maximum concentrations of trace metals in sewage sludge produced in California, as reported in the recent 1998 CASA survey, indicate that most metals would comply with the proposed limits under the GO. Copper, mercury, and selenium are the only trace metals in the 1998 CASA data for which maximum reported concentrations would exceed the ceiling concentration limits under the discharge prohibitions of the proposed GO regulation. Consequently, some biosolids produced in the state would require additional treatment to be available for land application under the proposed GO.
- g The proposed GO includes concentration limits and cumulative loading rates for chromium and molybdenum. The proposed GO is therefore more restrictive than the existing Part 503 regulations that do not include limits for these trace metals.
- g A large percentage of metals are bound in the surface soil layers and are not mobile in the aquatic environment.
- g Biosolids application is prohibited under wet or frozen conditions, thereby limiting potential infiltration and transport of dissolved trace metals to groundwater.
- g Depth to groundwater during normal biosolids application periods in summer is typically sufficient in most regions of the state to preclude substantial transport of trace metals to the water table. Areas that could have shallow groundwater are distributed throughout California, but these conditions can generally be present in areas such as the southern San Joaquin Valley where confining layers restrict downward movement of groundwater, near natural groundwater recharge areas such as large regional low areas, and near streams. In areas with shallow groundwater and frequent biosolids application, monitoring is required that would result in early detection if leaching of substantial quantities of pollutants were occurring.
- g There is a low probability that all the conditions suitable for metals transport would occur in California (i.e., high metals concentrations in biosolids, high biosolids application rates, low soil pH, and high rainfall conditions).

For the reasons described in this discussion, the impact of trace metals on surface water and groundwater is considered less than significant.

Mitigation Measures: No mitigation is required.

Impact: Potential Degradation of Surface Water and Groundwater from Synthetic Organic Compounds in Biosolids

Biosolids application to land has the potential to contribute SOC's to surface runoff or soil leachate beyond the plant root zone, which could eventually reach groundwater. For water quality impacts to occur, the concentration of runoff or leachate would have to exceed applicable regulatory water quality criteria (ambient water quality criteria for aquatic life, human health from consumption of organisms, or drinking water standards, whichever is lowest) or otherwise induce toxic effects in the aquatic environment. The potential for surface water runoff of biosolids is very low and the GO contains numerous minimum standards that the discharger must implement to control surface water runoff from the application site. As described above, provisions of the GO would require dischargers to implement appropriate BMPs, such as maintaining minimum setback distances from surface waters and wells, prohibiting application directly to surface waters, prohibiting application to saturated or frozen ground or areas subject to washout, preventing runoff for 30 days after application, and requiring that an erosion control plan be professionally prepared for areas with slopes greater than 10%. Consequently, the probability of washout is substantially reduced because biosolids application projects would have to be designed to meet the runoff prohibitions.

Potential impacts on groundwater quality were evaluated based on information developed for the Part 503 risk assessment process and other available data. The risk factors for increased leaching of organic compounds from biosolids into groundwater are based primarily on low soil organic matter content and microbial activity, high concentrations of organic compounds in the biosolids, and hydrologic conditions such as high rainfall or presence of shallow groundwater. In some areas in California, as described in the "Environmental Setting" section, one or more risk factors are higher than is the case under most conditions statewide. The major risk factors are related to hydrologic conditions that can contribute to increased groundwater concentrations such as the high rainfall areas of northern California and central coast, soils with low organic matter content (such as in some sandy soils), and shallow groundwater areas.

The potential impact of SOC's was evaluated based on the regulatory performance standards established under the GO, operational requirements for a discharger applying biosolids under the GO, or naturally occurring conditions that would result in low probabilities for water quality impairment. The following information describes types of impact mechanisms and mitigating factors or protections provided under the GO to reduce the potential impacts:

- g** The Part 503 risk assessment process for 14 contaminant pathways determined that the groundwater pathway was limiting only for DDT/DDE compounds. EPA subsequently eliminated all SOC's from consideration in the final Part 503 regulations because they failed to meet one of three screening criteria described above. DDT/DDE compounds were eliminated based on all three screening

criteria. Consequently, land application of biosolids under the GO for 15 years has a very low probability of exceeding risk thresholds that were developed on models that assumed application would occur annually for 100 years.

- g** Organic compounds are generally strongly bound in the surface soil layers and are not mobile in the aquatic environment.
- g** Biosolids application is prohibited during wet or frozen conditions, thereby limiting potential infiltration and transport of organic compounds to groundwater.
- g** Depth to groundwater at the time of normal biosolids application during summer is typically sufficient in most regions of the state to preclude substantial transport of organic compounds to the water table. Areas that could have shallow groundwater are distributed throughout California but are generally areas such as the southern San Joaquin Valley, where confining layers restrict downward movement of groundwater, near natural groundwater recharge areas such as large regional low areas, and near streams. In areas with shallow groundwater, monitoring is required that would result in early detection if leaching of substantial quantities of pollutants were occurring.
- g** Although not regulated with pollutant concentration or annual cumulative loading rate limits, the GO contains narrative limits that the land application of materials classified as hazardous waste are not allowed. The lack of discharge limits for organic compounds in the GO does not imply lack of discharger responsibility to meet applicable federal and state hazardous waste disposal laws. In addition, testing and reporting are required as part of the NOI process in the GO rules for PCBs, the pesticides aldrin and dieldrin, and SVOCs. Existing federal and state hazardous waste laws would be applicable to biosolids application projects, and testing may be required; the existing Part 503 regulations do not require testing for any organic compound. The testing would provide a means of evaluating the potential for soil accumulation and transport of organic compounds at land application sites. If it is found in the future that the land application of biosolids is responsible for unlawful disposal of hazardous waste, cleanup actions (if required) would be taken by the responsible parties.

For the reasons described above, the impact of SOC on surface water and groundwater quality is considered less than significant.

Mitigation Measures: No mitigation is required.

Impacts of Other Activities

Horticultural Use

The use of biosolids for horticultural purposes (for turfgrass production, cut-flower production, road medians, parks, and golf courses) would result in similar or fewer impacts on soil and water resources compared to those described above for agricultural use because applicable minimum standards under the GO would be the same, and it is expected that horticultural operations would account for substantially fewer acres of the available biosolids application areas. There would be no appreciable difference between the fate and transport of trace metals and SOC's discharged with biosolids for agricultural or horticultural uses because the same concentration and cumulative loading rate limits under the GO are applicable.

Silvicultural Use

The application of biosolids for silvicultural use would generally result in impacts on soil and water resources similar to those described for agricultural use because applicable minimum standards under the GO would be the same. Biosolids application projects in forested areas, which tend to have greater slopes than urban and agricultural areas, may have slightly greater potential for runoff of biosolids during extremely wet weather conditions. However, each RWQCB is required to review each NOI for compliance with the minimum standards under the GO, and each discharger would be required to maintain the same setback distances from water bodies and wells, implement controls for surface runoff and storage of biosolids, and have erosion control plans for steep slopes. There would be no appreciable difference between the fate and transport of trace metals and SOC's discharged with biosolids for agricultural or silvicultural uses because the same concentration and cumulative loading rate limits under the GO are applicable.

Land Reclamation

The use of biosolids for land reclamation would generally result in impacts on soil and water resources similar to those described for agricultural use because most applicable minimum standards under the GO would be the same, and it is expected that land reclamation would account for substantially fewer acres of the available biosolids application areas. Biosolids application projects at land reclamation sites may have slightly greater potential for water quality impacts on nitrate-sensitive groundwater basins because the dry-weight application rates would not be limited by agronomic rate of nitrogen uptake. However, each RWQCB is required to review each NOI for compliance with the minimum standards under the GO, and each discharger would be

required to maintain the same setback distances from water bodies and wells, implement controls for surface runoff and storage of biosolids, and have erosion control plans for steep slopes. There would be no appreciable difference between the fate and transport of trace metals and SOC's discharged with biosolids for agricultural or land reclamation sites because the same concentration and cumulative loading rate limits under the GO are applicable.